

NCC2-374

UNIVERSITY OF CALIFORNIA

Los Angeles

11-34

101521

**Enhancement of Nucleate Boiling Heat Flux  
on Macro/Micro-Structured Surfaces  
cooled by Multiple Impinging Jets**

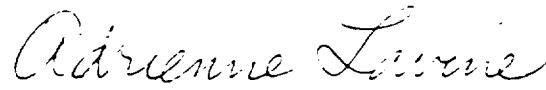
A thesis submitted in partial satisfaction of the  
requirements for the degree Master of Science  
in Mechanical Engineering

by

Scott Lee Kugler

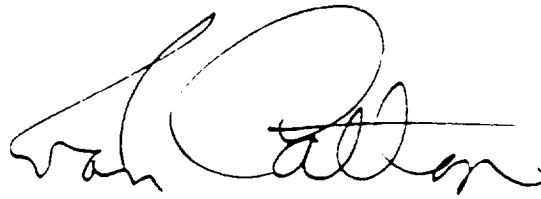
1997

The thesis of Scott Lee Kugler is approved.



---

Adrienne Lavine



---

Ivan Catton



---

Vijay K. Dhir, Committee Chair

University of California, Los Angeles

1997

## **ABSTRACT OF THE THESIS**

### **Enhancement of Nucleate Boiling Heat Flux on Macro/Micro-Structured Surfaces cooled by Multiple Impinging Jets**

by

**Scott Kugler**

**Master of Science in Mechanical Engineering**

**School of Engineering and Applied Science**

**University of California, Los Angeles, 1997**

**Professor Vijay K. Dhir, Chair**

An experimental investigation of nucleate boiling heat transfer from modified surfaces cooled by multiple in-line impinging circular jets is reported and found to agree with single jet results. A copper block is heated from the back by two electrical arcs, and cooled on the opposite side by three identical liquid jets of distilled water at subcoolings of 25°C, 50°C, and 77°C and Freon 113 at 24°C subcooling. Liquid flow rates are held

constant at 5, 10, and 15 GPH for each of the three jets, with jet velocities ranging from 1.4 m/s to 11.2 m/s and jet diameters from 0.95mm to 2.2 mm.

To increase the maximum heat flux (CHF) and heat removal rate, the boiling surface was modified by both macro and micro enhancements. Macro modification consists of machined radial grooves in the boiling surface arranged in an optimally designed pattern to allow better liquid distribution along the surface. These grooves also reduce splashing of liquid droplets, and provide “channels” to sweep away bubbles. Micro modification was achieved by flame spraying metal powder on the boiling surface, creating a porous, sintered surface.

With the addition of both micro and macro structured enhancements, maximum heat flux and nucleate boiling can be enhanced by more than 200%. Examination of each surface modification separately and together indicates that at lower superheats, the micro structure provides the enhanced heat transfer by providing more nucleation sites, while for higher superheats, the macro structure allows better liquid distribution and bubble removal. A correlation is presented to account for liquid subcoolings and surface enhancements, in addition to the geometrical and fluid properties previously reported in the literature.

## ACKNOWLEDGMENTS

I would like to thank Professor V. K. Dhir, Chair of the Mechanical and Aerospace Engineering Department, for all of his backing, encouragement, and invaluable support and commitment in my research. I am also grateful to Professor Ivan Catton and Professor Adrienne Lavine of the Mechanical and Aerospace Engineering Department for their guidance and time to review my thesis.

I would like to thank my parents for their encouragement and support throughout the many years leading up to this degree, and my wife Martha for her faith, passion, and inspiration for my success.

Finally, I would also like to thank NASA through their support of the NASA-UCLA Flight Systems Research Center, without which my studies would not have been possible. In addition, my colleagues and friends were instrumental in my learning throughout my research.